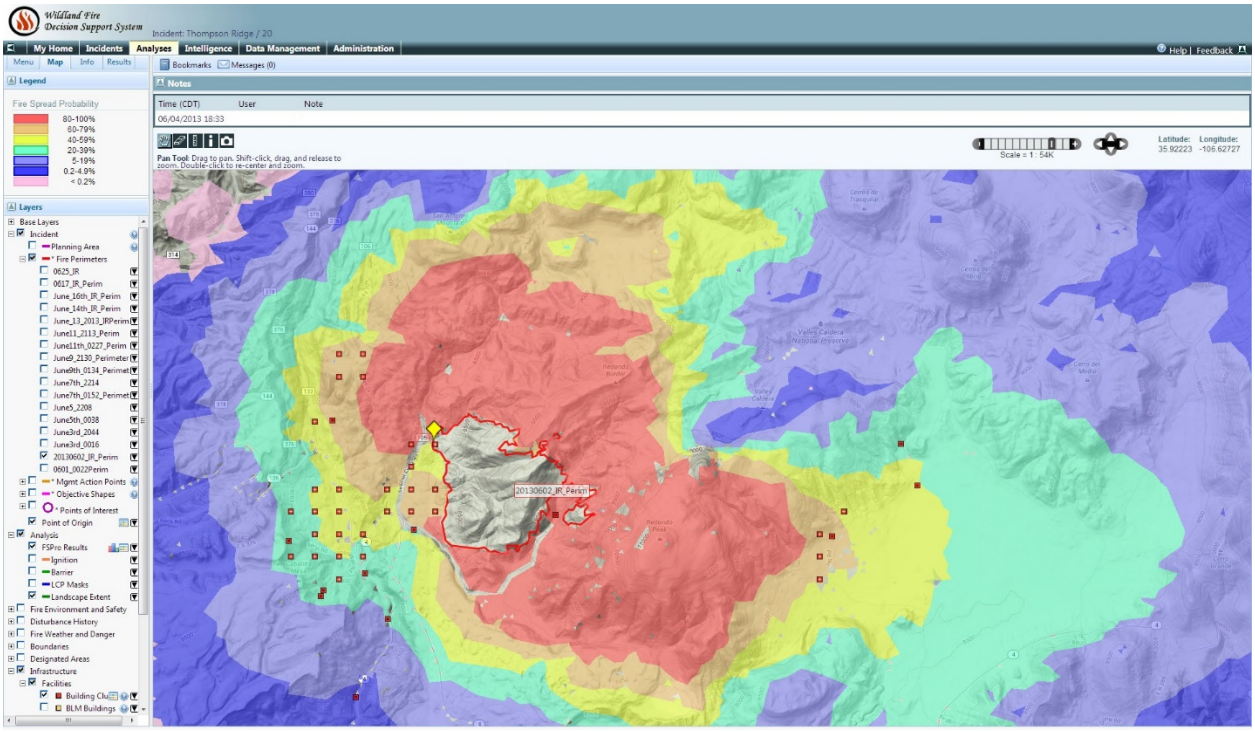
Wildland fire managers' use of fire weather data in strategic and tactical decision-making across the US (Western focus):

Phase One Interview Findings



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Executive Summary

Wildfire management decision-making is complex, dynamic, and not well understood. While many decisions are prescripted in decision support tools, there is considerable room for interpretation and adjustment according to local conditions. One source of information in this decision process is fire weather-based tools such as the National Fire Danger Rating System (NFDRS) and the Wildland Fire Decision Support System (WFDSS), which are used nationwide to support both strategic and tactical decisions. However, little is known about which fire weather-based tools most heavily impact fire management decisions and how managers actually incorporate output from these tools into their decision-making. This report summarizes the first phase of a research project designed to investigate these tools, their use, and their sensitivity to errors.

Exploratory, semi-structured interviews were conducted with 26 fire managers or technicians representing a broad range of management agencies (federal and state) in the western United States in March-May 2017. Positions include Incident Commanders, Section Chiefs, District Rangers, Fire Management Officers, Fire and Fuels Specialists, Unit Chiefs, Fire Behavior Analysts, and Program Managers, among others. Agencies include the USDA Forest Service and the USDI BLM, Fish & Wildlife Service, and National Park Service, as well as CALFIRE, Oregon Department of Forestry, NOAA, and NIFC. Participants had been stationed all over the United States but at the time of the interview were located in the following states: Arizona, California, Colorado, Idaho, Montana, Oregon, and Utah. Interview data were analyzed and organized into themes.

Overall, fire weather-based tools such as NFDRS and WFDSS were recognized and appreciated. For many individuals these tools are critical sources of information, though all participants acknowledged that the final decision relies on more information than just the model output. Participants also identified numerous other factors that influence fire management decision-making. Major findings include:

- In a pre-fire context, having resources prepped, staged, and trained is essential. This includes having WFDSS pre-populated and updated, which many participants report is not always the case.
- Initial attack decisions begin with whether to send resources to a new fire start or not (usually yes but not always). Pocket cards or run cards, which are written using NFDRS indices and landscape information, often determine what resources will be sent. An early decision to order a Type 1 or 2 team may also be made at this point. NFDRS or other fire behavior models do not play much part in decisions at this phase.
- Managed fire does not occur in some jurisdictions (e.g., CALFIRE), but when it is an option, it is only done in areas with very low potential and agency administrators may still be very nervous and not permit it. Fire weather information would be used to justify low potential, but politics often trump a team's interest in managing rather than suppressing a fire.
- Extended attack signals a significant increase in complexity in most cases, but more information also becomes available at this time as fire weather information is generally available and resources have had time to relocate to the fire if needed. Larger teams may be called in, which bring more resources and better support and organization. Fires may have multiple fronts that require different tactics at this point, even having distinctly different weather forecasts.
- Unnecessary mitigation actions are those made with little known effectiveness and/or higher risks than needed but often pushed by politics or public pressure. Participants expressed great

frustration about circumstances when pressured into taking what they considered to be unnecessary actions. An example would be flying retardant planes on a fire that was untouchable.

- Tradeoffs are constantly being made in fire management decision-making. Tradeoffs may be between strategies or between political risk and firefighter risk. Ecological values were often seen as being traded off for some other appearance of suppressing a fire. Letting a fire burn now was also identified as a tradeoff with reduced fire risk later.
- Tipping points or trigger points seem to be very common and imbedded in many aspects of fire management decision-making, yet they are often not individually identified as tipping points. They may be large scale or small scale and temporal or spatial, but are essentially a point at which another action is triggered. For example, if a fire reaches a particularly ridge, it triggers the evacuation of a nearby town. The decision to order a large Team may also be reached after a trigger point is surpassed.
- Information needs during a fire event are vast and cover numerous fields. Broadly speaking, they were lumped into forecasts, data sources, and communication in this research. Trusted, accurate forecasts were needed though not always available, particularly during initial attack or in locations with poor data resources. Data sources include fire weather models but which model varies by person and experience. Other data sources are personal experience, field conditions and observations, historical information, uncertainty, experts, and gut instinct. Communication was seen as the key to all information yet most recognized communication skills and training are lacking, and that communication fails are common and greatly increase risks. Real-time information is critical and must remain fresh to prevent complacency on the fire line.
- Values at risk were discussed by everyone. Public and firefighter safety was always named as number one (though some acknowledged actions didn't always seem to keep that value a priority). Other values include homes, infrastructure, communication and relationships, commercial values, recreational opportunities, wildlife, air quality, ecological and cultural values, and more.
- Timing plays a factor in decision-making because getting resources (whether that's information or crews or other) sometimes takes considerable time and fire proceeds whether a decision is made or not. Crews may also be more at risk with delays in action, both through complacency with information or boredom and the desire to take action. Time also increases uncertainty.
- Scale is important to consider because without the big picture, you don't have a true understanding of the local context and without focus on small details, the big picture is not well-informed. Scale is one way units often impact each other, as resources may need to be shared.
- Influencers on decisions were vast. Though not all impacted every situation, their strength could be very significant if that factor was present. Influencers included: politics (e.g., call from Governor's office), cost, resource availability, risk (general risk, risk aversion, risk to firefighters, and the hero complex), culture, trust from communities and within teams, and other contextual factors (landscape conditions, weather, proximity to WUI).
- Numerous models are used in decision-making. The most commonly named were WFDSS, NFDRS, FSPro, and FARsite. They are used for a variety of reasons, including looking up land management objectives, to communicate within and across teams, to run projections to inform forecasts and recommendations, to develop tipping points for action, to support decisions always made, model and/or justify costs, examine uncertainty, inform but not dictate decisions,

and compare against other models to find the most accurately predictive for an event, among other uses.

- Confidence in models is generally high, unless different conditions are experience in real-time, the individual has bad prior experience with models, or an untrained, non-expert is running the models. Shoulder season and longer-range predictions are also times when managers may have less confidence in models.
- Model limitations & inaccuracies are generally recognized and accepted as part of a model. Significant limitations/inaccuracies brought up include inability to incorporate real-time information, using historical data that is not reflective or the most recent fire behavior and climate trends, inability to model unusual green-up, the length of time to get models running well and how much this costs, reliance on RAWS stations that are not placed well or are in disrepair, and human error. The biggest human error was introduced when an untrained individual runs the programs because these models are very much a "garbage in, garbage out" kind of tool.

Brief Project Overview

Many fire weather-based tools, such as the National Fire Danger Rating System (NFDRS) and the Wildland Fire Decision Support System (WFDSS), are used nationwide to support the full range of strategic (pre-fire and prescribed fire planning) and tactical (initial and extended attack) wildland fire management decisions. However, little is known about which of these tools most heavily impact fire management decisions and even less is known about the sensitivity of those tools to input errors. To address this gap, we combine fire modeling with social science to explore the decisions that fire managers make, how fire weather-based tools are used in that process, which sources of error are the most influential for those tools and how various errors sources could impact decision making. The objective of this project is to addresses four key questions:

1. *What strategic and tactical decisions do fire managers make and how are fire models used in these decisions?*
2. *How sensitive are fire danger and fire behavior tools to various sources of input error?*
3. *How could model sensitivity impact tipping points that may lead to different fire management decisions?*
4. *How can we use this knowledge to improve the fire weather-based decision support tools and what are some needed future directions for fire modeling and decision science?*

This project is being implemented in four phases, each corresponding to the appropriate key question above. Phase One includes exploratory, semi-structured interviews with key agency personnel. Phase Two includes a sensitivity analysis of fire danger rating and fire behavior modelling tools to explore how fire weather inputs affect model outputs. This step will address the mostly frequently used tools and data sources that are identified through the exploratory steps in Phase One. Phase Three includes development of tactical (initial and extended attack) scenarios based on findings from Phases One and Two and with participatory input from managers (e.g., key interviews and review of drafted scenarios). A choice experiment using the developed scenarios will be conducted with managers on a national level. Phase Four will include synthesis of the results and development of recommendations for improving or changing fire weather tools. Engaging with managers and scientists to implement these changes will occur where possible.

Interview Methods

Exploratory, semi-structured interviews were conducted among a broad array of fire managers and forecasters, including Incident Commanders, Operations Section Chiefs, Planning Section Chiefs, District Rangers, Fire Management Officers, Unit and Battalion Chiefs, Regional Fire Management Coordinators, Fire Planners, Fire Management and Fuels Specialists, Fire Behavior Analysts, and others. Participants represented NOAA National Weather Service, the National Interagency Fire Center, the USDA Forest Service, the USDI BLM, National Park Service, and Fish & Wildlife Service, as well as state agencies including CALFIRE and the Oregon Department of Forestry. Participants had experience working all over the United States and some even internationally, though at the time of study they were stationed in the following locations: Arizona, California, Colorado, Idaho, Montana, Oregon, Utah and Georgia. Participants and locations were purposefully selected to cover a diverse range of positions, levels of authority, experience with fire weather modeling and forecasting, and geographic regions.

Participants were purposefully selected to represent a broad range of fire management positions, agencies, and geographic regions. Participants were identified from the study teams' working knowledge of this population, from local fire science network contacts, and from publicly-available employee information for government agencies. Additionally, some additional names were solicited using a snowball approach. Potential participants were first contacted either via email or through an in-person introduction if made on site with a snowball approach. The email/introduction included information about the overall study, the funding agency, potential benefits and risks, as well as anticipated time to participate and confidentiality protections.

Interviews were conducted on the phone and in offices and meeting locations between March and May 2017, lasting between 45 and 110 minutes. Most interviews were conducted individually, though a few occurred with two people at once. A total of 27 individuals were interviewed, after which new information was no longer surfacing (Robson 2011). All interviews were digitally recorded and transcribed, resulting in 588 pages of transcripts. The resulting transcripts were analyzed using NVivo 11.

Interview data were analyzed using an interpretive, directed contact analysis approach, looking at both manifest and latent content (Berg & Lune 2012). A researcher reviewed the transcripts, beginning with an interpretive, line-by-line coding process where phenomena are named and sorted into categories through close examination of the data (Robson 2011). A total of 69 codes were compared and built into eight coding frames (categories) which were later combined into broad themes related to our research questions and guided by existing literature (Berg & Lune 2012, Creswell 2013). A second researcher then followed the same approach to analyze 20% of the interviews, chosen at random. The two researchers then compared codes and frames to assess inter-coder reliability (consistency in approach between coders) (Robson 2011). A total of 284 points of comparison were identified within the random selection of interviews, of which 81.3% were considered similar. Differences in codes were reviewed and addressed. Results are presented here as key themes and sub-themes related to our research questions with direct quotes from participants to further illustrate and provide explanation of the theme. In many cases the quotes speak very clearly for themselves and are provided in their entirety.

Caveat: As interviewer on this project, I was humbled at the complexity of these situations and organizations. Though I have conducted research on fire-related topics for 15 years, I have never served as a firefighter. I have done my best to listen to and understand the structures and scenarios the participants described to me. I have attempted to describe them accurately here. However, the complexity, variation, and uncertainty of fire management decision-making makes it possible if not probable that I have inaccurately captured or described some information. I have done my best to avoid error. Yet, I recognize the potential for error may be high for some points in this analysis. It is important to remember that these events are very contextual, and they often unfold rapidly and in ways that allow for if not require improvisation. There is no "right" answer to these questions, nor one that all participants would necessarily agree on. With this caveat in mind, I present the findings for this interview project of fire managers on the topic of fire weather data use.

Decisions

The very broad range of decisions made makes it difficult to describe many specifics. Different decisions are made by different position types within the different agencies. Line officers make the ultimate decision about large objectives and prioritizing values to protect. When a line officer is serving as incident commander, they are ultimately responsible for many of the operational decisions as well. Incident command team members (ICs and Chiefs) are responsible for decisions about operational strategies. In order to give some basic description of the decisions reported on by participants, findings in this section are divided by phase in the fire management cycle and/or significance of the decision: pre-fire preparedness, initial attack, managed fire, extended attack, unnecessary mitigation actions, tradeoffs, tipping points, and information needs.

Pre-fire preparedness

Pre-fire decisions largely focused on having resources in place or actions completed so response to an event would be faster. Some participants talked about specific decisions/actions that are completed in order to be better prepared when a fire event does start. For example, ensuring contracts are executed for necessary resources (e.g., helicopters, local engine crews) enables faster response during initial attack. Other actions such as ensuring WFDSS is updated and fully populated were also mentioned as important decisions made in the pre-fire phase for faster initial attack response. Another decision one participant focused on was making sure he and his team understood their precise role within the team and how that evolved during an event. This begins long before an event and certainly aids in fostering a smooth team communication and interaction experience during an actual event.

Initial attack

The goal of initial attack is to respond within 2 hours and suppress 95% of new fire starts, keeping the fire at less than 10 acres in timber.

The most basic of decisions made in an initial attack circumstance is whether to send resources at all. In the very large majority of circumstances, resources are sent to monitor, manage, or suppress the fire. In some circumstances, however, a line officer must decide whether to withhold initial attack resources from one fire start in order to direct those resources towards another area with greater potential for growth. One line officer provided the following example:

> *So after a lightning event, we're gonna fly recon the next day for –park name--, find five different fires. Several of them, say, four of them, are burning in locations where they have very, very low potential. So they're gonna fuel out. They're gonna run out of fuel at some small size. A quarter of an acre, to maybe 10 acres. And we're probably not gonna do anything. Might monitor by air. One of those five fires is in a place where it's currently a quarter acre, burning in heavy fuel, has moderate to high potential over the course of the next several weeks, to grow to multi-thousands of acres. Maybe threatening some kind of infrastructure. We're gonna decide, likely, that we're gonna put that fire out. (1)*

When a new fire start is identified and it is determined that resources will be sent, some decisions are predetermined and some are not. Predetermined decisions include what specific resources will be sent using a ”run card” or “pocket card.” These cards include a standard set of resources that will go to new fire starts in different dispatch zones, which are set independently at different locations but typically include indices from NFDRS. Energy release component (ERC) seems to be the most dominant variable used to set dispatch zones. One participant provided the following example of predetermined resources sent at different dispatch levels:

> *If it's a level one, it might be just a response of a single engine to go out there and check it out. As fire danger increases, fire behavior will also be increasing. And so that's what we plan for. So, at a level three, a high level dispatch, it might include three or four engines, an airtac platform, two helicopters, two air tankers. It could be a couple hand crews all going to that same fire at that same spot at different levels. (13)*

Decisions that are not predetermined are varied, but include things like choosing to immediately order a Type 1 or 2 Incident Management Team. This may be done when fire danger and potential for growth is extremely high and when local resources are already taxed.

A perception shared by several participants that likely influences initial attack decision-making is that this initial response to new fire starts is when risk to firefighters is at its greatest. According to one participant, this is:

> *Because there's so many unknowns. We don't have a written plan. There’s no spot weather forecast yet developed. You don't have a map of that fire. You don't know how exactly it's going to burn. A lot of times you're taking actions with fewer resources, and so there could be a lot of chaos, especially if the fire's escalating. And you have a public that's trying to evacuate and others that are trying to get back in because of whatever reasons. I mean, there’s all kinds of stuff that you're dealing with. (13)*

Managed fire

When a fire is managed (rather than fully suppressed), it is “to achieve management objectives, or fuels treatment objectives” (1) and it is done in areas with very low potential. This is not the case for all agencies. CALFIRE suppresses all fires, though there is awareness of fire’s beneficial uses within as demonstrated by this CALFIRE participant:

> *There can be considered a pretty significant contrast between CALFIRE’s mission of putting out fires and a lot of the federal agencies missions of trying to recognize the beneficial uses of fire and use fire for resource benefit when it’s appropriate. So, it’s kind of a major difference in the paradigm and my agency has a long way to go to get to whenever we get to that point where we start doing that on a regular basis. (2)*

In contrast, when agency administrators agree to it, participants report that fires are being managed more frequently on other public lands and if they didn’t have to worry about public health and safety, they would manage every fire. Getting agency administrators to agree to allow management instead of

suppression, however, can sometimes be a challenge. As one participant said: "we have to convince the agency administrator to let this fire go" (7). Another participant added:

> *What I think gets those agency administrators a lot of times is that political side of it. They're saying I can't have smoke in the air for two months. I can't – you know, I can't have fire in our backyards for that long. Whatever it may be. That's where some of that comes into play. Just stop it where it's at. (11)*

Politics emerged as a barrier at numerous points in the interviews, as will become evident throughout this report. One other significant finding that emerged is recognition that any managed fire carries risks and managers can be nervous. As one participant divulged:

> *There was never, ever a prescribed burn that I implemented, and I've done a ton of them; I was a burn boss Type I and a Prescribed Fire Manager and stuff, and there was never a burn, other than pile burns in the snow, that I wasn't nervous and I didn't drive her nuts about the night before or the morning before I left. So, there's never a hundred percent. (14)*

Extended attack

As an incident grows in size and duration, the complexity seems to increase exponentially as more variables enter the scene. In terms of increased size, there is greater potential that a manager will be managing fire on multiple fronts. This can mean very different tactics are necessary to manage, monitor, or suppress the fire in different locations. An example provided by one participant illustrates this:

> *The interesting part was, in this case, about half of the fire was in a – moving into rehabilitation, and the other half was ripping. I mean, it was – but that part of the fire was moving into an area where there were far less values at risk, and the fire management units allowed for fire to quote-unquote "play it's natural role." So, that meant that you had very different activities going on in different parts of the fire. So, that presented challenges in terms of what resources you're ordering. (12)*

Another participant focused on the logistical complexities of extended attack and how a larger (Type 1 or 2) management team may be called in:

> *What's interesting is the duration of a fire – even if it doesn't grow big – is a variable and the reason is what gets you often is the logistics. They start running out of basic supplies and then the second part of that is the ability to continue to say manage it from a – how would I describe it – to be able to take care of the administrative part of a fire will really eat up a Type 3 organization. They don't have finances often. They have large costs going on. They're not being able to specifically track crews and helicopters and where this work's taking place and what this will look like tomorrow for you because they're operationally kind of maxed. So, it's really often something like logistics that'll make you go, "Hell, we gotta bring in a larger team" and to be able to move supplies around to them and understand where they're going and, when you do get resources, how to efficiently place them out there with all the stuff they need to be successful and be able to coordinate moving stuff aerially, to be able to drop stuff for them. (16)*

This increased demand for support in extended attack also means resource scarcity is more likely to come into play. Hot shot crews are the first thing to be completely obligated, as several participants indicated, yet heavy equipment and engines are generally available. It was also pointed out that fires in more remote areas generally require more resources too, primarily because those locations are difficult to access. Speaking about fires in steep, remote terrain, one participant said:

> *They tend to be very long duration fires. So, they're going to generally require resources for a very long period of time and especially with just the lack of roads and stuff like that. Then all of a sudden, you need a bunch of aviation support to help support the people out there – Whether it's to transport them, or feed them, or take care of them, and stuff like that. And for tactical use for water drops and stuff like that too. (25)*

In terms of having information to make these decisions about tactics and resource use, participants noted that by extended attack, they were much more likely to have fire weather model data to use in their decision-making process. As pointed out in the Model Limitations section below, it often takes a few days to get the models up and calibrated for the situation, so it wouldn't be until extended attack that they are a reliable source of information in most cases.

Unnecessary mitigation actions

This idea of "unnecessary" mitigation actions is not to suggest resources are intentionally used for the sake of waste and excess. Rather, these are actions and events that, in hindsight, were questioned by some for their purpose or necessity. The reasons for the use of these resources varied.

One sentiment that came up several times was ordering and using as many resources as possible when they were available as a way of ensuring they were on-site and ready for that event. As one manager said it:

> *If there's stuff, we'll order it. Like it's – there is never too much, so if there's stuff, we'll order it. If there's 15 VLATs, we're gonna fly 15 VLATs. If there's one, we're gonna fly one. (1)*

In many ways this is associated with what participants called the "Old Guard," from the period of the 10 AM policy where every fire is put out by 10 AM the next day. Another term used was "Suppression Dogs." One participants elaborated:

> *They're the Old Guard, and they can't help themselves. And we have had to just be after them, you know, "No, dropping retardant in the wilderness, that's a no-no. It's –" yeah, and they are just suppression dogs, and they just are used to putting fire out, and it's hard to back those people off from that. (24)*

Another sentiment shared with frustration was when resources are put towards a fire with such severe fire behavior that suppression is not going to be effective. One participant described such an event:

> *When it's just obvious that there's a lot of destruction going on out there. When you see a column that's 30, 40,000 feet in the air, and you're getting reports of multiple homes burning and evacuations are occurring, and all these kinds of things, we know it doesn't matter how*

> *many aircraft you throw at that fire, or how many firefighters you have on the ground, you're not gonna stop it. (13)*

The explanation from several was that these decisions are often made because of appearances and politics. For example, one participant admitted: "We've kept crews and helicopters on fires that have been long dead just for the perception that we're trying to save timber values in certain areas" (26). Another participant linked the political pressure with knowing the fire may be untouchable:

> *But you can go out and spend a whole lot of money – you can run retardant and aircraft all day long –and you knew it wasn't going to hold. Quite honestly – you've probably heard this or experienced it a little bit – there is the political side. You take actions, and there are things called political smokes – that it's out there and it's in the middle of the black and it's not going anywhere, but every day, the county commissioner is getting a call from 25 people – "What the hell! Put that fire out!" And the pressure is on, so they go fly aircraft and put water on it. That's reality. (18)*

A third critical connection here is potentially unnecessary risk to firefighters when suppression actions are ongoing with little chance of success but great political pressure. A participant explained:

> *There's enormous political pressure to appear to be taking action. And sometimes that involves enormous risk for firefighters on the ground, which I fight against all the time, of "Why are these guys out there?" … we're gonna fly retardant all day long and helicopters. And that's a huge amount of risk, and we've crashed tankers and we've crashed helicopters, not uncommonly. And so – but the aviation side of it is really, really popular, I'll say, because people see it. You know? (1)*

It seems clear that an important part of firefighting is *appearing* to fight the fire, which may lead to actions and risks that are not necessarily to successfully managing fire.

Tradeoffs

In addition to tradeoffs between multiple fires managed by one entity (described in "Initial attack" above), tradeoffs are a constant in fire management decision-making. The number of decisions that were described as a tradeoff was overwhelming, though it seemed these tradeoffs were not always recognized as a tradeoff because the choice was pressured or already chosen for some reason. The complexity of the tradeoffs a line officer faces were described clearly by one participant:

> *You start to balance some of these decisions about resource impacts, or – I think about it in terms of political pressure that a line officer gets. Because, you know, they put an area closure in place so hunters can't get in there, and so they're getting calls about that. But, you know, the reality is, yeah, maybe they could take a more aggressive approach and perhaps open that area sooner, because they put firefighters in there to take an aggressive approach on it. But at what risk, right? You're essentially switching political risk that the line officer may have for physical risk to firefighters out there digging line, when – again, you question was it really necessary? There's no houses out there. (12)*

The presence of political risk to line officers in making these tradeoff decisions came up frequently. Another participant talked about trading off the ecological value of fire against protecting a community against firefighter safety:

> *The landscapes are generally fairly well described in terms of those values, could be ecological, cultural values, or infrastructure, or visitor protection, and surrounding communities. And so those values, relative to potential, really help to make those initial decisions. And they're often is tradeoff, because the tradeoff may, if we decide to put the fire out, because we're concerned about the impact to a community, we've traded the ecological value of a fire. We've traded the fuels treatment value that we might have gotten from the fire. But we've also, in some cases maybe, traded those things relative to risk to firefighters. (1)*

Firefighter safety was a clear tradeoff in almost all decisions and will be described in more depth in the "Influencers on decisions" section.

Other common tradeoffs include consideration of values and potential future risks when waiting for a season-ending event rather than actively suppressing a fire, dealing with smoke impacts from fires that are managed rather than suppressed, and the use of aviation resources with the public demands to see action against the cost and relative effectiveness of these resources. Quotes demonstrating these topics follow, respectively:

> *Values at risk. If there's values at risk out there that they may – they said this is a priority for me, and we say well, if we continue to let this go, that priority's gonna be threatened. So, then, they'll say okay, go ahead and suppress it. Or if it's like well, we wanna wait till a season-ending event, well, you start running some of those models and that season-ending event's way out there, they'll say okay, let's go and suppress this. (11)*

> *But then you allow a fire to burn all summer long, and you're producing massive amounts of smoke, there's a public health concern. (13)*

> *The stuff you see on TV, which shapes a lot of what the public perception is – planes are flying and the retardant's flowing, right? A lot of that is a waste of money, quite honestly, and a lot of that is putting that pilot at risk. Well, there's people that say, "Well, that's what you're paid to do," and that's absolutely true. But now, we're getting more definitive –direction saying, "When want to manage this fire, you need to use a risk-based assessment –with a high probability of success." So, maybe this idea of trying to catch that –if you wait two days, let the winds die down, then you have a higher success, because the planes aren't in a more turbulent environment. You can actually maybe get people on the ground where it's not running through the crowns, and them with shovels, you know? (18)*

Tipping points

Tipping points, also known as trigger points or management action points, can be viewed on smaller and larger scales. One participant provided a nice description of how he viewed trigger points:

> *A trigger point means that when this fire moves to this trigger point that another action is taken. It triggers another action. Another common term which may be more important is a*

> *management action point is another, better term I think and the reason some people say map lines and they get confusing because they're lines they're putting on a map, but they're also called MAPS, management action points, but I think it's a better term and the reason is we collectively agree the management of this fire that some action's gonna take place at this point. When this fire hits this ridge, we're gonna go burn off another ridge or simply put, when a ten acre fire gets to the top of this slope, we're gonna put a dozer line in it. (16)*

Small-scale trigger points seem to be built into nearly every days' action on a fire and include decisions like where resources will be staged or which ridge will be used to defend. The participant went on to explain:

> *If the fire gets to this location, then that's a trigger for an action to take place somewhere further out or maybe the trigger would be to evacuate or maybe the trigger would be to close a highway. (16)*

Another trigger point for a change in daily behavior, as described by a few participants, was the issuing of a new red flag warning. Old red flag warnings did not have the same effect – it was the new warnings that caused the shift. One participant explaines:

> *Let's say you have a larger burnout plan or something, and again back to the weather predictions, and all of a sudden you show red flag warning, that would largely affect your operation. By and large you're going to see a change in tactics, where you're going to have a – more a decision point. (19)*

Another participant pointed out that trigger points can be both spatial and temporal, though he also suggested actually using trigger points in a strict sense because "politically incorrect" about 10-15 years ago. He explained several trigger point scenarios:

> *We would establish a point on a map, most – so, they're trigger points, and they would trigger an action or a reaction should the fire hit this point. The cool thing about these trigger points is they were both – they could be either temporal or special or even just a, sort of a criteria. For example, it could be a line on a map on a ridge that if the fire hits this ridge, we've got one day to evacuate a town. We could also use something temporal. If the fire – I was trying to think of an example – like at a certain time – I guess this is kind of a criteria. I've seen action points or trigger points based on relative humidity and temperature. Because the weather has been constant for two weeks, and we saw for the first few days, every time it hit a temperature and there was certain humidity, the fire really picked up and it was too dangerous for people to engage. So, there would be those kind of trigger points. (9)*

Some of these examples, such as evacuating a town, are larger-scale trigger points. Another example of a larger-scale trigger point, and one of the clearest examples of a trigger point that was reported by the participants was when an incident-within-an-incident occurs. This could include a severe injury, accident, death, burnover, or other significant event that causes an abrupt change in behavior and decision-making on that fire, such as described below:

> *Other things that come into play – you know, if you get a firefighter injury, firefighter burn over shelter deployment, definitely escalate to more resources. When we get a fire around homes or real people evacuation, you know, that type of thing. (5)*

Information needs

When considering decisions that may be made in an event, particularly in regards to fire weather, it is important to think about information needs. Universally, forecasts of weather and fire behavior are considered useful. Data sources are also important to consider, as some were considered more valuable than others. Each of these items are shared through communication, which meets many information needs as well.

Forecasts

Generally speaking, forecasts are understood to be valuable information and they are trusted as a probable future, not as a certain future. When preparing a recommendation for action, the forecast is a very important piece but not the only information that is considered. As one technician stated:

> *There's a lot of different models that are out there that are available and I'm familiar with most of them, but there's only, like I said, a handful that I actually use for making recommendations. I never make a recommendation solely based on what a model tells me. (13)*

When considering forecasts as a source of information, the more extended forecasts are viewed for trends but with the knowledge that the information can be pretty off. As another participant stated:

> *You're looking at the trends. Most of the time I like to focus a lot on which ways are conditions gonna trend; drier, moistier, windier, that kind of stuff, and then you can start to adjust from that. But you're right, the precision five days out is pretty bad. (14)*

Thinking specifically about the five-day forecast, another participant comments on its usefulness for resource preparation:

> *I wanted to know more about what was predicted not only for that day, but what the five-day forecast. And everything after five days I didn't really rely on, it was more of an awareness at that point. But that five-day window was making sure that we were staffed, making sure we had resources. (21)*

Several participants also talked about using personal experience and observations to weigh the accuracy of a forecast. A manager explained his take:

> *Sometimes it's easy. We can sit there and look at satellite imagery, and look at the prior run, and the most current run of a particular model, and go "This doesn't initialize right with the conditions I'm looking at. The flow in the atmosphere just doesn't quite line up with certain features that I'm looking at in satellite imagery." So that's one indication, where we can just sit there and say "I don't like that data set. I want to look at something else." So there's a lot of thought that goes into that. A lot of decision making. A lot of prior experience. (10)*

This was reiterated by another too, with attention to local unique situations:

> *You just wanna have a forester out there who's willing to recognize that, "I need to watch for anything that may be unique in our situation." That's where you get that experience that a model may not quite adequately determine. But for the most part, the model is based off of good reasoning. (23)*

There is also growing interest and enthusiasm for some of the newer forecasted products. For example:

> *The gridded forecasts though are getting better. That's a pretty cool thing. I mean you can click anywhere and the temps are coming right on. They've got some really cool models going with that one. (14)*

While forecasts are no doubt useful, there is also concern about how they may be misinterpreted, mostly by the public. One participant provides a good example of the potential misunderstanding:

> *How accurate is the weather forecast you watch every night? Okay? Fifty percent chance of showers. It didn't rain, they were wrong! It poured – boy, they were wrong! So – and having the background that I do, with the geek side of me –all they said there was a 50 percent chance of a shower – that could have lasted 30 seconds. Right? That meant that they were 100 percent accurate. (18)*

Data sources

Sources of data for needed information were consistent for some sources and more individualized for others. For example, while everyone in this study did use model output as an information source, the particular model they preferred sometimes varied (further discussed below in the Models section). And weather forecasts were always considered useful, but the length of forecast used varied somewhat from person to person. Historical information is sometimes used to understand current or potential future conditions. One participant explained:

> *We use similar historic weather data for a lot of other fire business decisions and a lot of other risk analysis tools (9)*

A caveat about using historical information is concern for how climate and fire behavior has changed in the last decade. For example:

> *If you look – just from a standpoint in the southwest, if you look at high temperatures and low humidity and wind, I think the last ten years are dramatically different than the first ten years. (9)*

For all sources, there was an acknowledged level of uncertainty that most participants discussed. For example:

> *We tend to accept a certain level of uncertainty when it comes to that and then, in order just to be able to move forward with our analyses. But almost every time that we do this that is one of the first questions that you ask, 'Is the data I'm looking at observed on the ground that we're*

> *subsequently gonna transform into some other data set for use of our modeling programs and things? Does that data make sense? Is it within the realm of reality?' (3)*

Expert input was considered a valuable data source by most. For example, having a meteorologist present on the team was preferred to leaning on reports without that expert guidance. When an expert wasn't available, using remote weather stations provided more localized data, as this participant explained:

> *The best is to have a meteorologist at your side. If you don't, we do deploy the fire RAWS at our remote stations and use those as our inputs. And a lot of times, then you're gauging – always in fire behavior, you're gauging whether or not you're on a severe end of a year. And so, I would pick a station in a severe year that it's at a more severe location, so maybe at a lower elevation that's reporting hotter and dryer than where we actually might be in the mountains. (24)*

A key concern about using data from the field is making sure that it is updated. One participant described this experience:

> *All that stuff relies on input from the field, and if you're not getting those inputs from the field reliably, you're not able to make decisions. If we're not using this stuff consistently, the managers know how to look at this information and know how to make decisions on it, but if the system isn't being fed, they can't make decisions on it, so that's a big deal. (27)*

Many participants, particularly those with more (sometimes decades) experience would also consider their gut a source of information. As one participant said:

> *I'm wrong, sometimes, of course, but I have some pretty good sense of what the fire's gonna do. Where's the highest probability the fire's gonna move today? Where's it gonna move to? What does that mean in terms of tactics? (1)*

For many it is a recognition of patterns, having seen similar circumstances in the past. This participant explained his experience well:

> *You see things repeat itself, and you're going "Last time this happened I went with this way, I went with this thinking, and my gut might be right." So, even here in first responders and the wildland fire community they have a lot of information that they're falling back on based on their own experience. It's just instantaneous. They say "I've seen this before. I'm gonna try this. Conditions seem to favor this decision." (10)*

This reliance on gut instinct may be a challenge to relying on model data as a data source, as this participant explained:

> *I think that's the biggest challenge of models and adding legitimacy to models is people focus on their guts and what – their experience base if you will, and their slide tray, they focus on that and a model has to be damn good to be able to break into that slide tray and chance the course. (14)*

Communication

Communication is critical to meeting all information needs. It ensures all involved are on the same page, as this participant explained:

> *All the different products that we put out. Very, very structured for decision support, so to speak. So working with emergency managers, and communicating to the public, and communicating amongst ourselves too is very, very important, so we're all on the same page. (10)*

Despite its importance, many research participants acknowledged communication skills and training are lacking. As one participant explained:

> *I think actually the tools are pretty well advanced in dealing with uncertainty. Our training as communicators of the information is lagging. And I don't know that there's even a great insight into this. I think that there is sort of a theme there for a finding, which is we need better training in risk communication even when we have quite expressive and functional tools that render risk information sound. (3)*

Another participant expands further:

> *We're not good at it at all, and we don't train line officers at all in that balance and that assessment of risk. We don't support them when they, they've made, I won't even say a bad decision, but they've made the wrong decision, maybe based on information or lack thereof. But that risk part is, is really big. And, again, the tools tie into that. If we had better tools. Well, then there'd be a lot less risk, or we'd understand the outcomes. The risk is in the unknown, and so how can you narrow that to something that's manageable? And for the unknown part, how do we support line officers in taking appropriate risk? And there is. There's risk. In every one of those decisions there's huge amounts of risk. (1)*

This participant also made a strong argument for getting real-time information into the hands of as many as possible. While he recognized this is difficult, he also noted it is a communication issue as much as anything, and we could do better on communicating. He also recommended drones for bringing real-time info to those who need it.

Further explanation by another participant demonstrates the importance of messages being passed:

> *When thunderstorms do form near a fire, close to the fire environment, yeah, that's a very critical time period. They're giving the crews out there a heads up on the radio. Something's being read to, and they're being told "Yeah, you got this outflow coming your way. Be prepared. Take the appropriate steps you need to to make sure you're in a good area and not a bad area when the fire comes through." So it's communications, my assessment of things, effectively communicating it, and if you can't effectively communicate it, the message is lost. You've got to have somebody that says it and receives it, they understand it, they – and it's – and then you take appropriate action. (10)*

Another questioned whether his message was actually reaching those guys out on the ground:

> *I still think there's a weak link there because, once it gets out there and it gets to the line supervision, is it getting all the way down to the brand-new guy that's running a Pulaski on a hand crew? I would hope so, but I don't know how you test that. (11)*

Communicating effectively also has its challenges, as several participants pointed out. One challenge is being in and out of cell phone coverage, as this inhibits not only the ability to share messages but the ability to use some modeling tools.

Another challenge is ensuring messages are delivered with language that will be understood. With too much lingo, the message will not be passed as intended, as one of the previous commenters highlighted. Another participant explained this challenge of communicating across groups:

> *I use that information when I'm briefing agency administrators or if I'm briefing my counterparts with other agencies, other fire chiefs, and also like with county commissioners and sheriffs and things like that that they don't necessarily know all the lingo and they don't know all our terms. And so I basically try to present the information to them in a way that they'll understand, to also help them understand how and why we're making decision the way we are. And so that's one of the things that's kind of tough is a lot of people unfortunately – I'm a fire behavior analyst, so I know a lot of the inner workings of how the models calculate and whether it's a fire danger model or if it's a fire behavior model and understand the differences between those. And then we have probability models. And so just trying to explain that in terms where people – it's useful to them, but not be like scared to death kind of thing. (13)*

Another participant also described this importance of catering to the audience:

> *We provide products – and by products, I mean fire behavior predictions. Just like any presentation, you tailor your information and geek-speak to the audience, so –there's certain things we show to –internal folks because they understand all the nuance behind it. If you're at a meeting, you don't want to take the time to explain all the nuance behind it, and yet a visual picture of what the fire's predicted to do, people take as gospel truth. "It's going to go there!" No, it's not. This is a prediction, and that's where we have to be very careful on how we present it, because, quite honestly, anybody can go and push these buttons for a lot of these models. (18)*

An important point is to make sure enough information is provided to those audiences in order to allow good interpretation. One participant expressed concern that maps in particular could be easily misinterpreted or seen as scary:

> *They see these maps, and these maps can be pretty intimidating sometimes or they can be kind of vague. And so people really don't understand how to use that information. (13)*

Another challenge that was mentioned and relates to how timing is a factor in decision-making (explored further below) is how to communicate critical information so that it stays fresh, even when it is the same message over a long period of time. For example:

> *I call that the chronic red flag warning. There's a chronic red flag on the Boise to the point where damn near all summer is a red flag warning – or a big chunk of the fire summer anyway – and the problem is that if you hear that every single day and every time, it becomes less meaningful. (16)*

This surfaced again with another participant who expressed worry about one label being applied to a very broad range of weather conditions. Specifically:

> *We'll get enough red flag days where it's kinda like, "Okay, I guess technically by the various criteria the weather service uses to declare it a red flag day, it's a red flag day." But on a Tuesday, you might have what is really obvious to everybody, "Okay, this is really bad if we have a fire today." Or, "Since we do have a fire today it's going to be a nasty, nasty day." And then the very next day it'll be like, "Wow, these conditions are so much less than they were, but it's still a red flag day." And then the next day is a red flag day, and then the next day is a red flag day. And it's kinda like, okay this is almost the point where it's starting to lose a little bit of its meaning (22)*

Communication, and challenges to communication, are a theme that spreads through nearly all aspects of fire management. For each other topic covered in this report, both above and below, there is reason to consider how communication plays into it. There is always some aspect related to communication.

Key factors in making a decision

Key factors that emerged when participants discussed making decisions were both explicitly and implicitly mentioned. Specific values were frequently named, and values at a risk as a general term was brought up by everyone. Issues of timing and scale also emerged in many scenarios when it came time for decisions to be made. Participants also mentioned specific information needs in order for some decisions to be made. Throughout this conversation, a number of influencers emerged that will also be discussed, including cost, politics, risk, trust, and general context among others.

Values

First and foremost, the most important and commonly-mentioned value that emerged from these interviews was that of public and firefighter safety. As one participant simply stated: "We're gonna prioritize firefighter and public safety always" (1). Interestingly, the very next thing from this participant's mouth was: "We say that anyway. We don't do that all the time." This sentiment of recognizing the prioritization of safety yet admitting decisions don't always seem to be in line with this priority was not uncommon. Fighting to protect other values under circumstances involving heightened political pressure was an oft-cited reason for this sort of dissonant decision. Becoming accustomed to risk was another reason, which will be described further in the section on Risk below.

Other values that frequently emerged include homes, infrastructure such as communication and utility corridors, communication and relationships among agencies and operators within a region, commercial values from timber or less-tangible items such as recreational opportunities, wildlife values, air quality, and more. Secondary homes and cabins were noted as less important than primary homes and key infrastructure. One participant talked about how subjective values can be, and that it can be hard to know which is most important. He said:

> *So it's kind of fun because we only started talking about values a handful of years ago. We kind of always managed for them, but now I think it's easier to talk about it because you can say, 'Well, this is a value, this is a value, this is a value.' The challenge of it is everybody is subjective, so everybody's view of a value is different, whether it's a standing tree either from a timber*

> *value standpoint or an ecological value input. So it's kind of a challenge for that. It's easier when you have community structures and people out there. That one's pretty straightforward. (14)*

A challenge in regards to values that emerged was how to handle fire crossing boundaries and spanning multiple jurisdictions. One participant described such a scenario:

> *Let's say you have forest service here on this side of the fire, you got parks service on this side of the fire, and you got state over here. Now, each one of them are gonna have their own priorities and values at risk that they're worried about. And then, you gotta sit them in the same room and say okay, here's all your values at risk. Now you guys need to prioritize them. Well, this guy's gonna say well, this is my No. 1 priority, and they're gonna go no, this is my No. 1. So, then, that's another tough thing that we need to deal with, work through that whole thing. (11)*

One very interesting observation about values that emerged has to do with how things are prioritized. One participant noted:

> *I just think it's really disappointing (…) that, say, ecological or cultural values [only] become important parts of decision making when there's very little risk. And if there is risk that relates to social infrastructure then those things become non-important, or considerably less important. (1)*

On the topic of ecological values and habitat, one participant explained:

> *If we're talking about from a habitat standpoint, or a certain species or something on the landscape, it changes tactics too. The way we maybe – don't employ heavy equipment. A lot of that counts in delegation. You may be in an area where you have a wilderness designation and there's already policy that guides what you can do there with mechanized equipment and blah, blah, blah. But, I would say – it's kind of a general answer – but I would absolutely, depending on the value at risk, what it is, it drives tactics completely. And, then as a result, those values that exist, hopefully go along with prior things and then guides our decision with tactics as to where we go first. (19)*

Finally, values can make fire management challenging in sometimes unexpected ways. In one example, a participant talked about having to keep access to a fire area open despite risks:

> *We were mandated not to close the road. And that's a different – totally different context of the value out there that you can't really put a finger on, per se. (19)*

Timing

Timing plays a major factor because response times for decisions and actions affect what happens on the ground and what decision space is available for consideration. For example, it may take several days to get WFDSS and other models loaded and calibrated before they can provide useful information, and during that time the fire burns on so some decisions are made without adequate information. As one manager explained:

> *You're using the best data that you have at the time, and sometimes you've got to bring in a whole team of folks to just do the modeling for you. And sometimes it takes days for them to kind of get things figured out. (13)*

This can also mean that if you take too long to make a decision or implement an action, then the decision is made for you. Another participant explained:

> *It's like there is no such thing as a no action alternative so if you sit there long enough it's gonna make decisions for you whether we're gonna manage this fire or put it out, those kinds of things. They used to drive me nuts, it's like, "What do you want to do with this fire? We need to decide now. If you wait an hour the decision will be made for you." (14)*

Another aspect related to timing is making sure crew remain vigilant and safe. A manager explains:

> *I'm just taking a guess – 85 percent of the time, nothing happens. So, then, the next time they say it, nothing happens. Next time they say it, nothing happens to affect the fire. It's that fourth time that it affects it. And people are – we're hearing that white noise. So, oh yeah they said it was gonna affect us the last three times and it didn't. And I think people kind of let their guard down a bit. (11)*

And another expands:

> *It's just making sure people kind of stay fresh, too, at that point. It's hot and dry for a month and hot and dry for the next month, you got to – You know, I just got to mix it up. I got to keep people from indifference, complacent. (21)*

Aside from indifference or complacency, one also needs to be concerned about crews becoming bored and choosing to take more risks. This will be further explored below in the section on Risk.

Movement of resources also takes considerable time, so a manager has to think ahead a few days about what they will need and where. For example:

> *It takes time for resources to move, so we're actually trying to look out probably the three to five-day time range, ideally, because if we're looking at one, two, and three days – well, it takes two days to move a crew, and then get them oriented, and stuff like that. (25)*

Generally speaking, longer time frames also mean more uncertainty, as circumstances can change rapidly with fire.

Scale

One of the most common comments about scale was the importance of taking in the big picture in order to understand the local context and recognize how events on their unit may impact others. This is well-explained by this manager:

> *I think a lot of people do try to do things realistically. But if you're not seeing the entire picture region wide, then I think your focus can be a little bit limited to some extent. My biggest thing that I've seen is when people aren't getting the resources that they're requesting. It seems to me*

> *it's important for them to know that they're actually helping to protect potential communities in other areas by not dealing with the things that they actually need to deal with. It's like an agency administrator of course wants to do everything around their specific fire, but they also need to feel like they're part of a big picture for leading a solution to a big picture and helping other communities also. (25)*

This can also be important for pool and/or prioritizing resources across larger landscapes. Another participant explains:

> *If we start getting lots of activity and we have some bigger fires, we'll pool together our local group, which is the three of us, and then we'll actually receive a briefing from our dispatch center manager, and we'll set priorities for the fires. We'll prioritize them based on the values that are at risk, and then we'll prioritize our resources. So whether it's aircraft, hotshot crews, airtac platforms, we'll set priorities, because a lot of times we could have multiple fires requesting air tankers at the same time, but we only have a handful of tankers to use, so we'll set the priorities on who's gonna get what resources, and then we'll order in additional resources to backfill so we're ready for the next new fires that we don't – that we know we're gonna have. (13)*

Thinking about the scale of an event is also important for requesting or requiring resources. In terms of housing and feeding a fire camp, there are certain cutoffs beyond which some resources (e.g., caterers) are mandated. The scale of an event can also be used to predict casualties, which suggests smaller units may be better. For example:

> *I can't remember the figures off the top of my head. But for every X number of people you expose to the act of fire line, then you can expect to have Y number of fatalities. So you can quantify it that way, and you can actually quantify it from ground resources to aviation resources on X number of hours. We can have a high probability of fatality based on those exposure hours. And the easier way for me to do the math is just the less people you have that are exposed, the less probability you have of having a fatality. (26)*

Another consideration is recognizing that the smaller your scale, the more specific decisions become. There is also no agreement on how close is too close for different risks. As one manager commented:

> *Two miles is probably okay for some people or five miles or never ever is good enough for some people. (21)*

Distance/scale can also get murky when considering smoke impacts, as they may be felt at great distances from an event, or may not be felt when close to an event depending on the direction of the wind. Another participant pointed out that some smoke events may cause great concern even if the fire is at a distance:

> *A fire that is ten miles away and it's putting up a lot of smoke, black smoke in particular, it's going to get people's attention and it doesn't matter if it's ten miles away or 15 miles away. (21)*

Influencers on decisions

In addition to the key items discussed above, a number of influencers were identified that sometimes played into decisions and if/how fire weather information was used.

Politics

Political pressure was one of the most mentioned influencers on fire management decisions. As one participant expressed:

> *So there is that political reality. And it's real. I mean, political pressure and expectations from legislators and the public, that's very real and relevant. You know? I'm never gonna suggest that that's not important, because it is. (1)*

An example scenario of the political pressure a line officer may be faced with was described by one:

> *It's hunting season. So, there's people who want to be out there hunting, and so the phones are ringing, you know? When are you gonna open my area? And in some cases, with outfitters, some cases, it's money. And so, you may actually get calls from county commissioners, or even state senators, or – asking why you're – you know, why do you have this area closed? I don't see – the fire's not burning anymore. So, those are, I think, some of the political realities that the line officers deal with, and that they're – they're there after the firefighters are gone, right? They have to deal with the public that they kept out of their favorite hunting areas, and so, the winter and fall – it's not just – and, you know, for years, right? It's not just a one-time thing. And so, I think, those are probably some of the considerations that line officers are looking at. (12)*

Politics can also create static boundaries that prevent flexibility when managing fire. For example:

> *Politics sometimes overrules things. And it frustrates me to no end when that happens. But I can sometimes understand why they do that. So – I mean I'll just give you a quick example. We had one time where there was record rainfall down in south central Oregon, Climate Falls Lake. They still started fire season June 1st. Get totally soaked. And it just politically in culpable to start it late, even though it was a totally wet May. And this happened, I don't know, 15 years ago. And it just humored me. It doesn't matter. They're gonna start June 1st. (23)*

Political pressure often emerges in the context of whether a fire is allowed to burn or must be aggressively suppressed. As one participants explained:

> *So they put pressure directly to the federal agencies, usually from DNR or ODF, the local land managers saying, "Hey, what are you doing? This isn't the right way to go." And, honestly, in the Northwest, that the federal land managers typically concede to that pressure, even though they might want to allow the fire to burn a few more acres so we're not exposing people to firefighters at risk. They get a lot of pressure for making it a smaller footprint and putting people out there. And we respond to that federal managers, which is too bad. (26)*

In some cases, the risk to firefighters may increase because of political pressure, as described here:

> *You know, sometimes there's politics that play into the suppression actions that occur. You know? There are times where there may be additional risk taking because of political pressures.*

> *We try to avoid that, but it's a tough thing to avoid sometimes. Well, I mean, just a phone call from the governor's office could change the direction of how a fire's being managed. We may have a fire that goes from a fire that we were trying to manage for resource benefits to, to now, all of a sudden, we're gonna suppress this fire, for whatever reasons. It could be affecting outfitters and guides. (13)*

Overall, it seems political pressure is a constant in fire management, whether there is a stated request or command at the time or not.

Cost

Cost emerged in a number of different contexts. While some discussed the awareness of how much excess is used in firefighting, it was also noted that firefighting provides for an open checkbook. As one participant said:

> *We are guilty of tremendous waste, and I think that we're not very good at accepting that that has impacts on everyone. So it has huge impacts on everybody else's work, because it's just an open check, you know? So they hire resources beyond what their budget is, because they're gonna charge them to fires. We don't do that in the Park Service, so all the preparedness resources we pay the base salary from our budget. (1)*

This sometimes creates conflict when costs are high and the objective is saving timber values, but the timber values may be less than the money spent on the effort to save them. Another participant explained:

> *"Keep it at the smallest footprint irrespective of the values at risks." So I think people go from the point that they think about the timber value, even in timber stands that don't have timber values. So they're always coming from a value place, even though it may be misplaced on that it actually has value. We've kept crews and helicopters on fires that have been long dead just for the perception that we're trying to save timber values in certain areas. (26)*

The importance of justifying and documenting costs also emerged. One participant explained this balance with requiring expensive resources:

> *If we're going to call in a bunch of huge air-tankers that are dumping a bunch of retardant, and that's the tactics or those are those are the game plans for the next day, it's to make sure that that is a tactic and expenditure because those are really expensive air-hops. And those things are in-line with the way we would want something managed. So, it's not just carte blanche, but to the IT, to the team, but there is a cost element. (21)*

One challenge about cost is the discrepancy between which regions of the country require fire money and which don't.

> *Everybody from back east, the senator and the – Maine goes why the hell am I spending all my – all of our money, giving to the Department of AG for the west? That does nothing for me. You know. I mean, there's that little battle that goes on politically, that – there's so much money spent fighting fire that – why are we spending and they never get it? (6)*

Resource availability

The availability of additional resources was definitely influential in fire management decision-making. Several interview participants commented on how creative they became when faced with few if any additional resources. For example:

> *Everything was gone. Out. Committed. Every hotshot crew. Every helicopter was committed somewhere. So going to large fires under those conditions you really – you have to be super creative because you're just not gonna get stuff, and it really changes our thinking strategy and tactics. What is it that we're gonna do? What can we be successful at? (1)*

These conversations about how to manage when additional resources are not available often spread to the agency adminstrators as well, as discussed here:

> *Basically, as an ops chief, we have to come up with a different strategy. We have to figure out – okay, well, we can't do that because we can't get the resources for that, so we need to back off and look at this. Or move to the road system four miles out, and we'll start prepping that road system, and we'll burn from there. And that's where we have all those conversations with the agency administrators, people that hired us to come help them, and say hey, here's the deal. We're on planning level 5, we can't get – we've got two hotshot crews and that's all we're getting, so we're gonna have to back off and look at some other options. So, it definitely affects our tactics and our strategies, that's for sure. (11)*

This knowledge that sometimes additional resources are not available has led to some (perhaps many) managers choosing to over-order so that they have resources in their back pocket. In other words, they would rather have it than risk not having it. For example:

> *I would rather go heavier than lighter. Obviously, I'm ordering resources, so if I'm, like, well, we might be able to get by with three task force of whatever – engines or whatever it may be – I'll order maybe four or five because I don't wanna just get by. I wanna be able to have that extra stuff in my back pocket. If it's available. We start getting into planning level 4 and planning level 5, and resources are tough to get. Really tough to get. (11)*

And as discussed above in the section on Scale, resource availability can lead to smaller units pooling together and prioritizing regional resources across larger landscapes.

Risk

Risk is an underlying factor in pretty much all stages of fire management. As many research subjects pointed out, fire management really is all about balancing risks. Generally speaking, fire management is known to be a risk averse business and several participants commented on why they think it is like this. For example:

> *I think a lot of line officers didn't come from a fire background. And fire, when you see it on CNN, it is burning through town. And so, that's where all that risk-averseness comes from. (24)*

However, others pointed out that comfort with operation in this risk balance often comes with experience as one interviewee points out:

> *I can tell you a big factor – again, difficult to measure – is people, just the individual comfort in making decisions one way or another; or another way to look at it is people's comfort in risk, acceptable risk. And very closely related to that comfort is an experience level. I think it's proportional; those that are more – but not universal. Generally speaking, those decision makers that have more experience, whether quantity or quality, tend to be more comfortable in the risk analysis decision-making process and usually make a better informed decision. And, of course, I'm sweeping with a broad brush when I say that. (9)*

In many cases, this may be balancing the risk of losing some value on the landscape versus putting firefighter lives at risk. One participant explains:

> *That's where you start to balance some of these decisions about resource impacts, or – I think about it in terms of political pressure that a line officer gets. Because, you know, they put an area closure in place so hunters can't get in there, and so they're getting calls about that. But, you know, the reality is, yeah, maybe they could take a more aggressive approach and perhaps open that area sooner, because they put firefighters in there to take an aggressive approach on it. But at what risk, right? You're essentially switching political risk that the line officer may have for physical risk to firefighters out there digging line, when – again, you question was it really necessary? (12)*

Repeated exposure to risk can also lead to becoming desensitized to risks, as another participant pointed out:

> *We become desensitized, to some fashion, as to truly what the hazards – what the risks are. And then, all of a sudden, you find yourself in this fire going "Oops." (10)*

It isn't just the firefighters who may become desensitized to risks either. One participant talked about negotiating with a private landowner who wanted his timber values protected. He explains:

> *At end of the day, and you ask them, "Hey, look. Here's the deal, we can burn off another 100 acres of your timber, or we can stand the risk of having to haul firefighters out of here in body bags." A lot of times, you have to just put it to them right simply. And when you put it to them right simply, they're like, "Nope, burn the timber. Don't let anybody get hurt trying to protect it." (27)*

The desensitization of risk carries to the media and the public as well, though firefighters are still at risk. Another participant explains:

> *The stuff you see on TV, which shapes a lot of what the public perception is – planes are flying and the retardant's flowing, right? A lot of that is a waste of money, quite honestly, and a lot of that is putting that pilot at risk. (18)*

One way to think about this desensitization of risks is to consider how fatalities are often treated as heroes. This hero complex idea overlaps with the section on Culture below. Not to argue that they aren't heroes, but some participants questioned whether this hero complex behavior may be encouraging riskier behavior. Speaking frankly, one participant articulated this well:

> *We're gonna prioritize firefighter and public safety always. We say that anyway. We don't do that all the time. That's an important part of a scenario too, is to kind of test that idea with people, because we say that every fire. First priority is public and firefighter safety, and then we do all kinds of stupid shit that put firefighters at risk. All the time. (1)*

And another participant expands:

> *I'd say in the last five, the ability for us to turn those fatalities into heroes, in that these people were heroic in what they did, and they died doing it is, I doubt if it's a direct conscious decision of justifying putting people out there, but on the flip side of that, and some of my friends have talked about, seeing more firefighter fatalities could get really blown out of proportion, and the parades, and things. We should honor these folks, but in some ways, it puts another rock on the other side of the scale about that exposure. (26)*

This desensitization of risks also surfaces when considering timing (from above). It can lead to choosing to take riskier actions because they become bored. For example:

> *Sometimes it's impatience because it's like we've been screwing around with this chunk of – the flank of the fire for two weeks. Let's put out – shove some crews in there. Put it out. And eventually, if you sit there long enough – this happens all the time – if you sit there long enough, eventually someone's gonna poke the snake. If you have hotshot crews that are sitting there and there's some nasty chunk of dirt, and we've said from the start "We're not gonna put anybody down there," this is – I don't want to tell war stories, but I have too many of them to not. But that's what happens a lot, is you say "No." You say "It's too high risk," and then eventually nothing happens, the fire sits there, or some bored hotshot crews are like "Oh, yeah. We'll go down there." And then all of a sudden they're in some crappy place. Like, bam. (1)*

Considering risks to firefighters specifically, participants were asked when those risks were greatest. Initial attack was the overwhelming answer, and when asked why, this emulates a common response:

> *Because there's so many unknowns. We don't have a written plan. There's no spot weather forecast yet developed. You don't have a map of that fire. You don't know how exactly it's going to burn. A lot of times you're taking actions with fewer resources, and so there could be a lot of chaos, especially if the fire's escalating. And you have a public that's trying to evacuate and others that are trying to get back in because of whatever reasons. I mean, there's all kinds of stuff that you're dealing with. (13)*

Despite the risky behaviors commonly reported by participants, some indicated that they felt fire management was getting better at balancing risks in a way that better protected lives. Specifically, identifying when resources are not valuable enough to fight for, and choosing not to engage when probability of success is low. For example:

> *We don't look at a snag patch and say, "Yeah, we're putting every firefighter in there because that's what's gonna burn." It's changed the way we've approached some of the – on a much larger scale, it's changed the way we've approached some of the strategic decisions that are made about whether to put a fire out or just back off to a road and burn out. We're not gonna put people into massive areas of tens of 1,000s of acres of snags. (22)*

And another expands:

> *I think it's come to the point now that we won't sacrifice our people, obviously, based on the values at risk. So, if they're saying hey, we wanna keep it tight. You know, keep this small, and we're saying we're gonna be putting a lot of firefighters at risk, that's a tough conversation, as I was talking about earlier. We'll back off. We'll let it go do – let it burn up more country, and stop where we won't have those firefighters at risk. (11)*

Culture

Culture is related to perceptions of risk as presented above. The fire-fighting culture is strong and built on decades of behavior with risks and losses. In addition to several of the Risk comments above, recognition of culture emerged with several participants. One person talked about the hero complex as part of the fire culture:

> *Saving trees? Forget it! They'll grow back. That's the hardest thing. And, of course, I'm not being – trying not to be judgmental as far as why they were out there. Part of that's the culture, right? We're heroes. (18)*

When asked why teams are placed at risk, one participant explained:

> *Sometimes it has to do with really important values that we really are, are trying hard to protect. Same of it has to do with the culture that we've built around fighting fire. It's a huge part of it. Some of it just has to do with, sort of, bad decision making, and this routine, and this sort of rote response to "We're here to put the fire out. Let's go." (1)*

This culture is stronger in some places than in others too. California, with CALFIRE, is known for being suppression only, which certainly impacts the fire culture as this participant points out with a connection to education:

> *Well, I was gonna say, I think there's a lot of – we have a loss of degrees, and that's more and more prevalent, it seems to me, in CAL FIRE, just doesn't have an understanding of forestry stuff. You know, that's played into it, too, a little bit. And they've been brought up in the California culture. You put every fire out. At least on state and private lands. (5)*

Despite the long-standing culture, some participants acknowledged the culture may be changing. This participant relates this change to an acceptance and appreciation for new technology as a good information source in addition to personal experience and gut feelings:

> *Some of those other folks love it when they have an operations person come ask them about something really gritty. Because that's kind of a paradigm and culture shift that you're starting to see, I think to where our operations people aren't the old ops chief where – I've been here, done this, I'm just going with what my gut feeling is. Now they're asking for reference or confirmation of what they're thinking, and realize that technology in those predictions are a good thing that can help us. (19)*

Trust

Trust certainly emerged as a strong influencer on decisions, both from communities and within teams. Trust from communities was described as sometimes tenuous, and while community meetings and having decision-makers engage with community members certainly provided trust-building opportunities, some aspects of trust from the community are based on visual perceptions and understanding of the fire phenomenon. As one participant described:

> *We do a lot of community meetings and let people know what's going on out there. So, our public information officers will put public meetings together, and they'll bring an ops chief in, and they'll bring the IC, and maybe safety or – they'll bring a few people in these meetings so we can answer questions and tell them what's going on out there. But you're right. If they don't see aircraft flying, they're like, what're you doing? (11)*

Related to this visual perception and understanding of fire is how one escaped prescribed fire can sink a trusting relationship. For example:

> *Well, right, and you know I mean fundamental to prescribe fire is the age-old adage that you can have a hundred successful ones and no one really pays too much attention and you have one loss and you're sunk. (3)*

In many respects this trust from communities is intertwined with political pressure, as discussed above. Part of the reason this connection is made is because teams often find themselves interfacing with local cooperators, which can include local elected officials. For example:

> *The typical one we always get is provide for the firefighter and public safety is a big one. Another big one is something around the relationships within the area with cooperators, meaning the last one I was on, we had to deal a lot with emergency managers for each county, county commissioners, and then the fire chiefs within those counties. And it really spoke to making sure we have good communication, coordination and cooperation with those folks. So that requires a certain part of the team to really focus and make sure we got all that going on from the minute we arrive until the day we leave. There's a whole group that works and pushes that. All functions deal with it, but your liaison officers really push that and work hard to make sure we're building those relationships. And a lot of times, if they're good already we're just maintaining them; we're not making them worse. (2)*

Trust from communities is certainly influenced by media coverage and the perceived success of management and suppression efforts.

Trust within teams emerged as a stronger factor in this study. As described by this participant, many managers and technicians have to rebuild their reputation with a new team every time they are given a new assignment:

> *You have to build your street cred almost every time you go into one of these organizations, unless you come in as one of the guys with a reputation for being one of the fire dogs. A lot of times it's who the information is coming from and how it's delivered, and how you build that street cred. One of the techniques I use is it's critical to go out to the field when you're doing the fire behavior work. My first trips out to the field I'm looking for Superintendents and I talk to*

> *them. I try to gather information from them on what they're seeing, then I validate it, and then I fold that into my analysis and forecast in such a way that that Superintendent or the other crew's Superintendent can see that guy took the information we provided and is using it. There's nothing that builds street cred with the ground pounders than seeing their information being used. (2)*

As pointed out by that research subject, communication and providing evidence that information is being heard and incorporated into analysis and/or decisions is key to building trust within teams. Another participant also talked about building that relationship with the new guy:

> *And when we go out as a team, the team knows each other. That person we don't know. We get them ordered in, and so that's one of the first introductions when he comes in, and I tell him, hey, I'm gonna be in your back pocket all the time. I'm gonna be looking over your shoulder when you're looking at the radar. You know, I need to know what our temperature trends are gonna be, our RH trends are gonna be, what – you know, winds, in what direction, and all that stuff. So, there's a close connection there. (11)*

And from the perspective of the new guy, trust is recognized as a relationship that takes a process (and time) to develop, as described here:

> *I really try to understand what their perspective is first. And then I can go to the analytical side to see what data we have to be able to communicate that most effectively from their perspective. And every fire is different, every line officer is different, and it usually takes a nice curve of trust, time getting to know one another until they are really listening to the input that I'm giving them from the analyst to be able to make decisions. So that's my process and how I do it. And also a lot of maps. (26)*

This expands further than just the new guy too. One participant talked about how trust plays into the decision about whether to stick with a Type 3 team or order a Type 2 team. He explains the appeal of a Type 3:

> *a Type 3 organization is really appealing for a local line officer and the reason is that a Type 3 organization typically has local resources from top to bottom. Now, we will bring in other crews and stuff, but I'm saying the overhead in a lot of the divisions, the field folks, are you know them so you kind of know. It's just more comfortable to be working with people you know, right? (16)*

Beyond these relationships that are often built face-to-face and with personal interaction, there is also some basic level of trust in the system, as this participant said:

> *The whole point of the team is the relationships you build. Doesn't mean – just like, when you meet someone new, and they're skilled, and you have faith in the system, that they have a set of experience and skills bringing with them. It's different than working with the same people. There's just another connection, or whatever it is. (18)*

The bottom line is that trust within teams, whether built through personal experience or present because of a trust in the fire management system, is critical to the smooth operation of a team and ultimately to the success of an operation.

Context

Context in this report is a general term that refers to many of the local circumstances that may influence decisions that have not been reported thus far. Many of the above influencers were actually part of "context" in the initial analysis, but warranted specific discussion here because of their strong importance. Other contextual items certainly exist, including but not limited to local landscape conditions, weather, and proximity to values as risk, including the WUI.

Weather factors that are critical to management decisions are fairly universal. This is summed up quickly by one participant:

> *Relative humidity is very important, temperature is very important, wind speed, that kinda stuff, are important because those factors are a concern about the start of a fire and the spread of a fire are key factors. (23)*

Proximity to WUI was recognized as a common reason for FMU's (fire management units) to be labeled as suppression, as described in the following two quotes:

> *So in the middle of the woods, you think you're in the middle of nowhere, there's all kinds of people that live on the river, and all – scattered all over the land, and eventually fires are gonna intersect their private property. And they expect some action (1)*

> *The FMUs that are suppression – I mean, that's a hard and fast, right? With the exception of safety risks, there's gonna be aggressive action taken in that FMU to put the fire out, to minimize acreage. Because – for whatever reason, but most likely, it's because there's infrastructure there, whether that's houses in the urban interface (12)*

Proximity to WUI can also cause some parts of larger fires to be let go in order to focus protection on the WUI, as this participant described:

> *"Okay, we aren't gonna catch this fire here. This community is over here, let's just abandon this and go here, protect our values and focus over there" and just not even deal with that part. (14)*

This potential impact on a community is also weighed in how the WUI will be defended too. Managers consider how management choices may result in a fire running into a community, versus a fire backing in (which is considered safer). For example:

> *"Okay, what is the potential for this community to be impacted within the next time frame?" And part of my job is to say, "Okay, not just what is likely to be effected and when? But also, the degree of the effect." Because there's a difference between a head fire running into a community and a fire backing into a community also. (25)*

Proximity to WUI is also a concern because of smoke, and though wind certainly extends the potential reach of smoke impacts, a nearby community is certainly reason to be concerned about smoke as this participant described:

> *With the proximity of the communities. So there's – smoke is always one of the things that we evaluate for – if we make a decision to allow a fire to burn or not. (13)*

Model use in decisions

A large variety of models are consulted for a large variety of purposes. Participants appreciated one-stop shopping, but also appreciated the ability to dig deeper into standalone products for customized tweaking. They universally recognized that the technical knowledge to run most of these programs and get quality output from them is vast; "Joe Firefighter" can't sit down and get good runs out of this stuff. Confidence in the programs was recognized and seems to be increasing, though limitations and inaccuracies were the common subject of many stories.

Which models

While there are a few models that were the focus of this research, numerous were mentioned during the interviews. The most commonly discussed models/frameworks were WFDSS (Wildland Fire Decision Support System), NFDRS (National Fire Danger Rating System), FSPro, and FARsite (Federal Acquisition Regulation Site). These will be explored in greater detail below. Others mentioned were FireFamilyPlus, WIMS (Weather Information Management System), BehavePlus, WinWizard, WinGen, FlamMap, GFS (Global Forecast System), WindNinja, NFMAS (National Fire Management Analysis), NAM (North American Mesoscale Forecast System), and NBM (National Blend of Models). These were all named specifically, though some of them are components within others in the list.

WFDSS

WFDSS is used to look up land management objectives, to run analyses on current and projected conditions, and to document decisions. It is also used as a standardized communication tool. Many participants were generally happy with having access to such a powerful tool, as this individual expressed:

> *I use WFDSS as a fire behavior analyst because of the tools that it contains for fire behavior. Common tools I'll use would be BehavePlus, but one of the things that's happened is many of the tools used to be standalone tools; FSPro, Farsite, these are some fire analysis tools that were out there. They've done a really good job of incorporating that into the WFDSS system, so that is really the preferred place to go in and do that kind of analysis. (2)*

Others, however, shared concerns about it seeming too easy to operate, which can result in untrained individuals trying to run analyses that then produce faulty results. For example:

> *WFDSS – it's made – they're trying to take the people – the thinking part of fire-behavior person out of it and trying to make it so you can push a button, and you're not gonna get accurate answers with it. Especially straight out of the box. And that's why I think – that's why most people don't trust it, most line officers, because they have Joe Firefighter at their office that has a login and can go on and put a perimeter or a spot in, and it doesn't match at all what the fire's doing. And they don't really have the – they don't teach that you have to go in and start modifying stuff to match what's actually on the ground. (7)*

Some participants described which circumstances would cause them to back out of WFDSS and use the stand-alone products. One circumstance is when there is no internet connection. Another is looking at historical information:

> *We still do use – or, at least, we use – FARSITE, just because you can ask a lot more questions of it. Some of the questions we get will – so, if – what's the hottest or the worst fire weather in June, and how would that affect our fire? There's no way to do that in WFDSS. There's no way to do back and do historical stuff. You can only do forecast and short-term stuff. (7)*

One important comment made by several participants was that all the data layers and updated objectives were not always preloaded into WFDSS when a new fire event started, and that often caused a lag in time before the output could be useful. Participants noted that having WFDSS "ready to go" would be a big asset.

NFDRS

While respondents were certainly familiar with NFDRS, few talked about using it often, though many aspects of the analysis and decision-making they discussed referred to indices in NFDRS so it is assumed they use it more often than they thought to mention. Some participants did explain how they use NFDRS in detail. For example:

> *We use NFDRS in very similar ways that everybody does. It's just a model that predicts fuel conditions based on weather and past conditions. And so, our seven-day model is built around the NFDRS output. So basically, what we're doing is we're taking the NFDRS output and forecasting it out to seven days. And then, using our knowledge of breakpoints and thresholds of indices on the time of year to assess the state of the fuels. And then, we use our meteorology expertise to understand that if these weather conditions develop, it's going to affect NFDRS indices this way. It's going to make them worse, or it's going to improve it, and that's going to have this impact on fire fighting. (17)*

Another participant pointed out that the station information included in NFDRS was helpful for him. It allowed him to understand more about the local conditions without having to go around and personally ask people. He explains:

> *I actually am one of the few people I know who ask for NFDRS plans on wildfire because it often identifies the key stations and the concerns that management had for those units, so you don't have to guess, or you don't have to go around and interview everyone. I do always interview the Forest and particularly their fuels people, but that always has the key elements in it. (24)*

When prompted to talk about it specifically, one concern that was raised had to do with relevancy of the data used to inform the indices. One participant explained:

> *If I'm not mistaken, NFDRS traditionally uses either a 10 or a 20 year data set, and if you look – just from a standpoint in the southwest, if you look at high temperatures and low humidity and wind, I think the last ten years are dramatically different than the first ten years. (9)*

Despite this, this participant and others acknowledged they know efforts are being made to keep the indices as updated and relevant as possible. Though no one verbalized it exactly, I got the impression that the users would appreciate being told explicitly what range of data was used to create the indices so they would understand the trends that were incorporated to inform NFDRS.

FSPro

FSPro was the program that was explicitly stated by the most participants as something they use, whether integrated in WFDSS or standalone. Most participants also had a story about times when FSPro was totally off (when the fire lands in the "pink"). That one prediction that turned out to be incorrect had a negative impact on how many participants viewed the overall model capabilities, though many still put a lot of trust in the predictions. One participant explained his reliance on the program:

> *FSPro is modeling these many, many, many scenarios, and it's usually pretty – that, that high probability footprint, is usually pretty accurate, or it's pretty close. So we tend to – I tend to have a high degree of confidence in those parts of the model that, say, almost guarantee the fire's gonna be here. Well, it's pretty likely that it's gonna be there. (1)*

One reason some participants stated that models such as FSPro may not be consulted and trusted as often as they could be is because they do not have the models running with suppression activities taken into account. Another participant explains:

> *We may not have seen the FS Pro while we were fighting the fire, but we look at it afterwards, it's like, wow, that's right on. And then, the models ignore suppression, so that's the other part, is where – you know, we continue to build line, we continue to order resources, and the model is ignoring all that. So, that's why, a lot of times, the model doesn't, you know, totally get believed in, but it's still a tool for us to use. (5)*

Some participants expressed concern about how FSPro model output may be interpreted by others. Specially, they worried the maps may be looked at as a progression rather than a probability. Communicating with non-fire and model professions could be a challenge, as this participant explained:

> *FS Pro spits out burn probability surfaces, and communicating that to individuals is not a simple thing. You think you've done a good job and they oftentimes leave the room thinking much more simplistically that the blue areas of the fire, which are the least likely for the fire to be there in two weeks, represent not necessarily a probability but a much more sort of gut level problem. (3)*

And this participant put it in the context of time:

> *You show people FS Pro and they think it's a progression – they think the fire's going to go there. So, that's why we rarely show that to the public, because we don't have the time nor want to take the time – and there's just this certain level –of –ability of the public to absorb (18)*

Overall, however, the tool was recognized as one of great value for fire management.

FARsite

Though an integrated part of WFDSS, FARsite was also used as a standalone product at certain times. One reason is to run certain analyses that are not possible in WFDSS. For example:

> *We use – FARSITE, just because you can ask a lot more questions of it. Some of the questions we get will – so, if – what's the hottest or the worst fire weather in June, and how would that affect our fire? There's no way to do that in WFDSS. There's no way to do back and do historical stuff. You can only do forecast and short-term stuff. (8)*

Like mentioned above, the standalone program is used when there is no internet connection, which is required for WFDSS. Another participant also liked how FARsite made it easy to adjust temperatures, while it is more difficult and tedious to do in WFDSS:

> *That's one gripe I've always had with WFDSS is they give you where you can change the hourly weather one hour at a time for days. In FARSITE, you can go in and say increase all my temperatures by five degrees and hit one button, and everything changes. (7)*

FARsite also contains more updated information than WFDSS in some locations. As one participant explained:

> *They don't update it (WFDSS) until the entire – the US has been updated. So, like, right now, we can use FARSITE because our area's been updated for 2014. It's not available in WFDSS. (7)*

One appreciation that was expressed about FARsite was the wind data it incorporates. Specifically:

> *In FARSITE, you have Wind Ninjas incorporated in everything, so you have better wind inputs. And that is, I think, the key with FARSITE is that you have that input of Wind Ninja, yeah, and it's not just straight stream winds. (24)*

How the models are used

Explanations about how the models are used surfaces throughout this report. As has already been discussed, the models are used to look at historical outcomes, to inform new forecasts, to communicate with line officers and others, to support a decision already made, to model and/or justify costs, to examine uncertainty, and to inform but not dictate decisions. Please refer to the appropriate sections for some of those comments.

Models are consulted multiple times per day in many circumstances, as this participant explained:

> *So we take these models two, maybe four, times a day, and we're always assessing the changes in the forecast…So we look at a lot of different models. There's just – I mean, sometimes it's just, I think, too much information. (10)*

Another way that models are used, particularly when modeling weather, is to compare them to each other and identify which one is most accurately reflecting true conditions. This helps forecasters ensure they are providing the best information, even if they primarily rely on the output from just one model. As this individual explained:

> *We have six, seven different atmospheric models. We try to figure out which one is performing the best. And then we forecast these, applying some local statistical curves, you know, what's our high? What's our low gonna be? What is the wind gonna be? And then we paint a picture on a grid. (15)*

Confidence

There is generally a high level of confidence in model output, unless different conditions can be seen. Confidence in model output can sometimes be retroactively questioned, particularly when there is an anomalous event. One participant explained his experience:

> *So the lowest probability colors are like pink and yellow. Pink, I think, is the lowest probability outcome. And we get bit in the ass by the pink all the time, in that the pink is out there and you're like "Oh, super low probability that this is gonna occur," and then we're in the pink. And that's happened to us many times. (1)*

Though these events are not exactly rare, most participants understood it is not necessarily a reflection on the model. For example:

> *Anomalies happen. So, on a personal level, the – to me I don't have a trust issue of the modeling cause I guess I understand that it's a model. (9)*

Many participants talked about a growing confidence in models, simply because people are becoming more exposed to them and have more experience and understanding. This participant explained well:

> *It's getting better a little bit, I think, because people are more used to computers, but when it first came out, people just automatically said it was garbage because they interpreted outputs incorrectly. And so, it's been – there's always – when new things come out, you always have to educate the users or the end users on what it means. And, you know, then, if it's garbage in and you get garbage out, and you're telling them this is what it gave us, you know (7)*

Some participants also talked about how confidence is also tied to the complexity of the situation. Specifically, in areas with considerable variability, there is less confidence in the ability of the models to project accurate conditions. This participant explained it well:

> *You can spend a whole two weeks and never really get that confidence necessarily, and a lot of that has to do with our dissected, mountainous terrain. It's just infinite variables – there are patches of roadkill out there that you didn't know, or you didn't map, or you didn't make your landscape edits on – that has a tremendous amount of driving the fire. There's certain triggers, like overnight humidity recovery – if it doesn't go much higher than 40 percent versus 70 percent recovery, then by 10 a.m., then that whole landscape is ready to burn earlier in the day versus mid-afternoon, which is typically the peak burning conditions. (18)*

Shoulder season (the very beginning or end of fire season) is also a time when there is less confidence in the models, because the models are built primarily on high fire season data. This participant has high confidence during the active fire season:

> *The overall model is fairly sound. I've basically kind of given you those areas where it has some problems and it's usually toward mostly the beginning of the season and then its good reasons that that happens. But once you get into the fire season itself, it seems to behave quite well. And it's not gonna fail you. It's gonna give you a pretty good situation. (23)*

Another perspective shared by several is that ground-truthing some of the model output improves confidence in the general performance. When ground-truthed, the models actually tend to overpredict, which is seen better than underpredicting. This participant shares his perspective:

> You need to ground truth the results. Has it actually happened? Is what is happening actually happening? I think overall, if you just did any of the fire spread models and let it run, it's probably going to over – if you've got reasonable weather and field moisture input, it's probably going to over predict what is actually happening out there. And there's a variety of factors associated with that, but fires tend to get checked in places. But it depends on the situation. There's potential for things to spot across, something that it can check, or there's potential for it to check it's something. And I think the models don't do a very good job at checking the fire to some extent. (25*)*

Finally, a universal recognition in model confidence is that the further out you run a prediction, the more uncertainty it will include so confidence goes down. For example:

> *Better – the closer you are in time to something, let's say from like 24 hours to the first three days, is usually the optimal time to forecast. The further you go in time and space and distance, things become more uncertain. (10)*

Limitations & Inaccuracies

Limitations and inaccuracies seemed to be well-identified and accepted by most participants.

Probably the most commonly mentioned limitation is that models do not have the capacity to incorporate real-time information. This was a request from nearly every participant – that real-time information about weather – particularly wind – be incorporated into all fire behavior and spread models.

An oft-cited inaccuracy that surfaced above in regards to confidence is that historical data is included which does not reflect more current fire behavior and events. As one participant said:

> *We can probably throw out the first year, first ten years of data because it's been dramatically different the last ten years. So anyway, if that's what's going on with FSPro or FARSITE or whatever's running these colored maps then sure, we probably ought to fix that. (9)*

And another added:

> *We're getting fires during the nontraditional summer fire season. A lot of things the models – you know, crown fire versus surface fire – a lot of things the models aren't designed for are happening. (3)*

One of the more technical interviewees talked specifically about how predicting these extreme events is difficult:

> *Some of the most interesting and important outcomes are a result of black swan events; they're rare, and by their very nature of they're rare we don't actually have a good idea of their probability. So you can apply a bunch of generalized expected values, statistical techniques on those and they're all sort of fairly shaky. I've gotten into this fairly deeply with my climatology work for the PUC where we're potentially looking at one in like 1,700 year kinds of weather events. And we're relying on either a ten-year or a 30-year data capture and extrapolating the right-hand tail. (3)*

Another area where the model was recognized as being often inaccurate was during periods of unusual green-up. As this participant explained:

> *Green-up's another one. Green-up basically means is that over the wintertime, so you have the life cycle of live fuels. So, you have dead fuel moisture and you have live fuel moisture. Live fuel moisture is much more variable than dead fuel moisture. Now, dead fuel moisture varies depending on how much moisture is on the ground, snow, rain and all that kinda stuff. But then over time, since it's dead and it has no inputs into the system, that dead fuel moisture dries out and it dries out significantly. Live fuel moisture is basically anything that's growing. So, live fuel moisture can vary considerably, depending on the time of year. Usually in the wintertime into early spring, before we have green-up, when other words, things start, the buds start breaking out and you start seeing leaves on the trees, and grass is growing, all that kinda stuff, we just kinda what's called green-up, you have pretty much dead fuel moisture, or dead stuff on the ground. You know, when you have the old grass, you have the old brush, it's got the leaves on it, things like that, the trees with no leaves on it. So, again, we're concerned about what carries the fire. So, that's gonna be stuff that's on the ground. So, at that point, you get a different fire danger during that time that typically in most areas, here especially on the west side of the Cascades, it's so soakin' wet anyway in the springtime or before spring that it's not an issue. So, let's say you're on the east side of the Cascades and we have a dry period through the wintertime. You can actually, and it gets warm. Like let's say, you can have some warm days in late February and March, before you actually start green-ups. And fires can start during that time and that's because you have dead fuel moisture that's dried out and you don't have anything live. Nothin's growin' yet. (23)*

Another limitation is the length of time that is sometimes needed to properly populate and calibrate a model so that it provides good information. This surfaces in a number of conversations and different contexts. And it wasn't just the time that was seen as a limitation – it was also the cost to pay those people who have to get it going. This participant acknowledged that given the time and resources, they could get the models running very well but the models were limited when they couldn't put in that effort:

> *We always run the model initially on pretty much the default fuel, the default weather, the default whatever, just to see where it's gonna go. And then – the model's not gonna be accurate until you calibrate it for at least a couple days of good perimeters. After, you know – and the ops folks know that, and that's something that we tell them right up front. Hey, this – we're using our default stuff on here. Get back with us on what you're seeing out there, and we'll take the*

> *infrared and try to match up, make the model – tweak the model to match what's actually happening on the ground. After a – usually, after a couple of days, we get really good at it. Matters fires are great because the firefighters aren't messing with them, and we can get our spread rates and stuff down within six-hour accuracy. But it does take a lot – it does take tweaking. It doesn't work out of the box at all. (7)*

Somewhat related to this is the source of the data that is an input to these models. RAWS stations were oft-mentioned both for their importance and value and for their inaccuracy and limitations. As one participant explained:

> *I think our RAWS are a great tool, primarily, for a fire danger system, for fire danger rating, and for really kind of given as a field where we're at with conditions over a very large area. And I think that's their primary intent and what they were designed to do. So if you have a fire that's in close proximity to a RAWS, great, but to just try and say "We're gonna have a RAWS network that covers real time across this huge landscape" would be just cost prohibitive. (13)*

Even maintaining the stations that are currently deployed can be cost-prohibitive in times of budget uncertainty, as this participant pointed out:

> *We've got a lot of RAWS stations that are – they've got sensors that haven't been updated, they haven't been replaced, they're – they're not calibrated correctly. We've got – that's a huge issue with maintenance on the RAWS systems, and it's very costly to do that. And to add even more to that, it's gonna make it even more complex, I mean, we recently did an exercise of recently trying to consolidate the number of RAWS stations, and the Department of Interior shut down a lot of them, just because of the cost of maintaining them and local units not keeping track of what their sensors are doing. (13)*

So the most accurate predictions are mostly limited to regions that have good RAWS coverage, though even with good coverage, some RAWS stations are in disrepair or not located well. Participants shared stories of finding components of the stations in useless conditions, such as when a fuel moisture stick was laying on the ground, or when the station was in heavy timber so wind would not be measured accurately.

One final limitation and source of error to mention is human error. This is related to confidence in the models, as it often surfaced when an untrained individual or one with little experience tweaking the system was asked to make predictions. Because they were not aware of all the ways to make the models more accurate, it would result in inaccurate information. This sentiment surfaced with most participants, as the education and training required to run these models and provide good output can be extensive. The result is that many units don't have that capacity in-house, so less trained individuals end up inadvertently bringing in more human error.

Manuscript Idea

Fire weather and behavior model use in fire management: the dream and the reality

- The dream (the ideal)
    - What is decision support really supposed to do?
        - Evaluating alternatives – WFDSS doesn't do this, it is a documentation tool as opposed to decision support tool
    - How could the info be used
    - With what intention would the info be used
    - What is the highest possible accuracy in ideal conditions
- The reality
    - How is the info actually used (data sources)
        - What else influences decisions – gut/instinct
    - Confidence in the information
        - Source of confidence/lack of confidence
    - Key factors in decisions – context and influencers
- Future
    - Improvements

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